

# The Taphonomy of Resource Intensification: Zooarchaeological Implications of Resource Scarcity Among Bofi and Aka Forest Foragers

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**Abstract** Zooarchaeological analyses often rely on bone fragmentation, cut marks, and other taphonomic indicators to bolster interpretations of resource intensification that are based on observed changes in prey types and frequencies. While these taphonomic indicators are assumed to be good proxy measures of processing effort, this assumption is based on inadequate actualistic data and analysts often conflate one or more taphonomic indicators as manifestations of the same process. In this paper, we present zooarchaeological data from two villages occupied by Central African forest foragers with very different foraging efficiencies. These data provide the first case where known disparities in diet breadth and foraging efficiency are matched with prey assemblages and taphonomic attributes. Observational and quantitative data show differences between the villages in diet breadth and access to high-ranked prey, but specific taphonomic indicators such as cut mark distribution and intensity do not match predictions generated from models of resource intensification. We propose that linking different taphonomic processes to resource scarcity and intensification can provide powerful adjunctive information. However, because different processing outcomes may be associated with different kinds of resource intensification in response to different kinds of scarcity, we need to strengthen the validity of purported taphonomic indicators with more rigorous independent studies.

**Keywords** Taphonomy · Foraging models · Resource intensification  
Ethnoarchaeology · Central Africa

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## Introduction

Analyses of zooarchaeological assemblages created by prehistoric hunter-gatherers often identify intensification resulting from decreased foraging efficiency associated with some sort of resource depression (see, e.g., Broughton 1994a, 1997; Butler 2000; Butler 2001; Cannon 2000; Janetski 1997; Lyman 2003a; Nagaoka 2002a, 2005; Stiner and Munro 2002; Wolverton 2005). The identification of resource intensification associated with declining foraging efficiency is often identified as one of a constellation of “push” factors giving rise to social, political, and technological complexity among hunter-gatherers (e.g., Cohen 1977; Hildebrandt and Jones 1992; Sassaman 2004) and experimentation with domesticatable resources (Munro 2004). Intensification is also often viewed as an index of resource stress—a factor in declining health, activity levels and fertility, increased interpersonal violence, and changes in life history among contemporary populations (e.g., Broughton and O’Connell 1999; Jasienska 2001; Jenike 1996; Leonard 1992; Yessner 1994).

Resource intensification is predicted under a variety of circumstances and has multiple meanings in the anthropological literature (e.g., Boserup 1965; Butler and Campbell 2004; Earle 1980; Morrison 1994). But a number of current zooarchaeological applications refer to the process whereby total productivity per unit of labor is increased at an increased cost to the individual. Some of these same analyses invoke rationale derived from the prey and patch choice models with strong theoretical foundations in human behavioral ecology to make predictions about the composition of the zooarchaeological record. The prey choice model ranks resources along a single dimension of profitability and predicts the order in which resources are added to and deleted from the diet. Important predictions of the model are that foragers always pursue high-ranked prey whenever they are encountered and that resources are incorporated into the diet in rank order. As the encounter rate with high-ranked prey decreases, foragers increase search time and broaden their diet to include lower-ranked resources. The patch choice model predicts which patches a forager exploits when resources are heterogeneously distributed (MacArthur and Pianka 1966) and, if used in conjunction with the marginal value theorem, can be used to predict when a forager should abandon one patch for another (or the giving up time) under circumstances where foraging gradually depletes the patch (Charnov 1976; Charnov *et al.* 1976). Accordingly, a forager should leave a patch when it is depleted to the point where foraging in another patch will yield higher returns per unit of time, including travel costs. Since the optimal time allocation in any patch is a function of the average yields for all patches in the habitat, as the overall productivity of the habitat increases, less time should be spent in any one patch. Conversely, if overall productivity decreases, more time should be spent in a chosen patch. When this logic is applied to prey, and animal carcasses are viewed as patches, the amount of time and effort invested processing a prey item should vary inversely with environmental productivity (see Burger *et al.* 2005; Fancher 2009; Grayson 1988, 1989). Thus, increased foraging time or effort in a particular patch reveals important information about overall environmental productivity.

Intensification is often identified as one potential response to declining foraging efficiency linked to exploitation depression or aboriginal overhunting (Broughton 1994a, b, 1997, 1999; Butler 2000; Grayson 1991, 2001; Nagaoka 2002a, b and/or

decreases in the absolute abundance of prey caused by ecological changes (Betts and Friesen 2006). As the local abundance of high-ranked prey becomes depleted, foragers respond by increasing search costs and incorporating lower-ranked prey (or patches) into the diet, traveling to more distant patches to procure prey, increasing the number of patches used, and/or intensifying how prey or patches are exploited (Broughton 1994a, 1997, 1999; Cannon 2000; Nagaoka 2002a, b; but see Grayson and Cannon 1999, p. 148; Butler and Campbell 2004, p. 338). In zooarchaeological assemblages, intensification of patch or prey use is often measured by taphonomic indicators, which are assumed to be proxy indices of increased processing effort (e.g., Burger *et al.* 2005; Fancher *et al.* 2004; Fancher 2009). These indicators include changes in cut mark frequencies, high levels of bone fragmentation, and marrow exploitation of low-value body parts (see, e.g., Broughton 1999, p. 64; Nagaoka 2005; Munro and Bar-Oz 2005; Potter 1995).

The use of taphonomic indicators, however, presumes (1) that all potential sources of taphonomic variability are known and (2) that there is an unambiguous link between proxy measures of processing effort and resource intensification (a so-called taphonomic signature). The difficulty of establishing these principles is particularly well illustrated in the current controversy over the factors that influence cut mark frequencies on animal bones. Based on his experience among Nunamiut Eskimo, Binford (1984, p. 71, 1986, 1988, pp. 127–131) argued that cut mark frequencies, excluding dismemberment marks, varied positively with the effort invested in butchery (but see Bunn and Kroll 1986). But subsequent actualistic studies show that cut mark frequencies vary as a function of many factors including (but not limited to) bone shape, tool type and material, site context, degree of bone fragmentation, carcass size and condition, the amount of attached tissue, as well as the desired end product (see Lyman 1987, 1994, 2005; Dewbury and Russell 2007). Recent well-controlled ethnoarchaeological and experimental studies have failed to generate consensus concerning which of these factors are the most influential in determining cut mark frequencies (Braun *et al.* 2008; Domínguez-Rodrigo 1997, 1999; Egeland 2003; Lupo and O'Connell 2002; Pobiner and Braun 2005). The lack of clear-cut patterning between cut mark frequencies and expectations led Lyman (2005:1730) to identify variability in cut mark frequencies as a central, yet unresolved, theme in taphonomy.

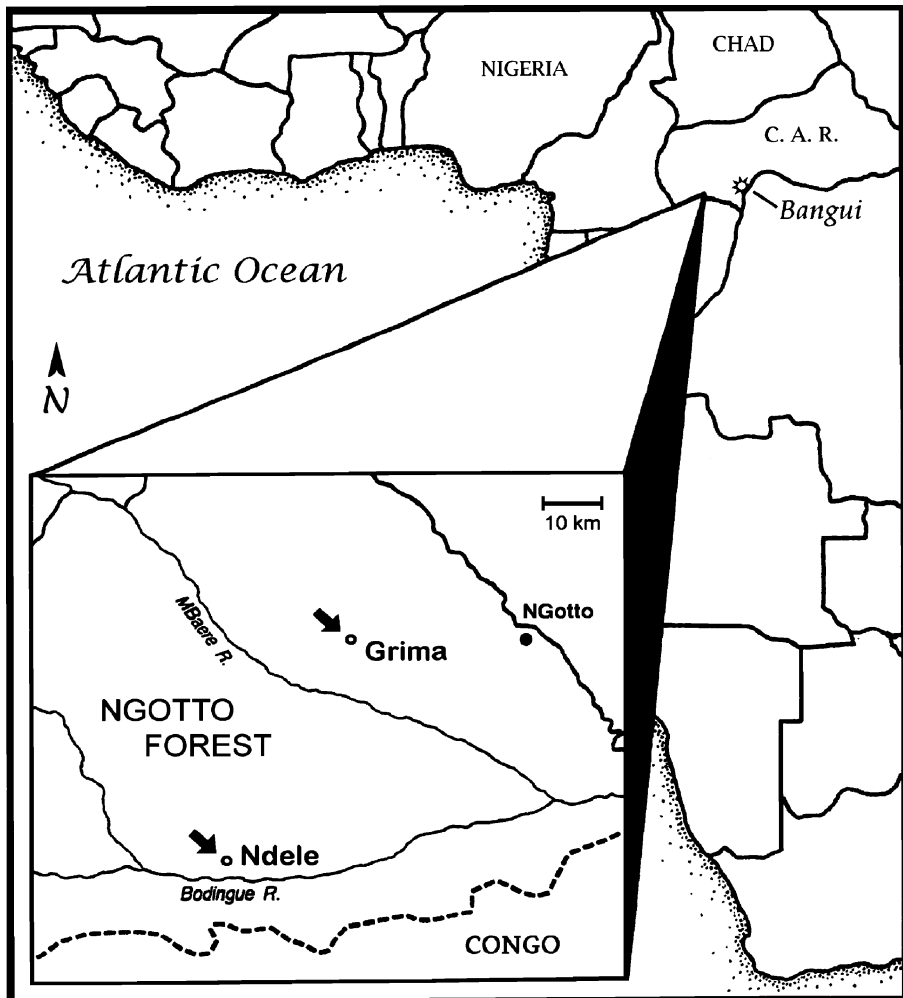
So far, independent evidence establishing an unambiguous link between taphonomic damage and processing intensity and, by extension, resource depression is rather limited. Only a handful of anecdotal ethnographic studies exist that describe the potential taphonomic outcome resulting from resource depression (Binford 1978; Gould 1996). But none of these actually demonstrate direct linkages between the different kinds of resource depression, intensification, and different taphonomic indicators. The problem is further complicated by the fact that resource depression can take different forms, resulting in different behavioral and physiological outcomes for human populations and, undoubtedly, different taphonomic expressions. For instance, behavioral or microhabitat depression can be short-lived, in contrast to exploitation depression, which often has a longer recovery time (Charnov *et al.* 1976). Depending on the importance of the resource, chronic depression resulting from overexploitation or other factors can result in a reduction in the overall quantity of calories available for consumption and/or can create qualitative deficiencies in

specific food groups. These conditions are not necessarily mutually exclusive, but they need not occur in tandem either. Scarcity in the form of reduced kilocalories is a different scenario from qualitative dietary deficiencies, and each of these has a different behavioral and physiological response. Clearly, understanding if, when, and how different kinds of taphonomic phenomena are linked to intensification and different kinds of resource scarcity remain important, yet unresolved, goals.

In this paper, we analyze two unique empirical datasets comprising quantitative measures of hunting efficiency and bone assemblages produced by Central African forest foragers to evaluate the value of butchery mark frequencies and marrow exploitation patterns as proxy indicators of resource intensification. These datasets were collected from two different study villages inhabited by related populations of Bofi and Aka forest foragers. We begin by presenting quantitative differences in foraging efficiency between the villages. These differences are one result of reduced prey availability caused by a combination of habitat depletion and overexploitation. The second portion of this paper compares taphonomic indicators derived from prey bone assemblages (so-called meal assemblages) created by the Bofi and Aka who occupied the study villages. We test the null hypotheses that there are no differences in butchery mark frequencies and the degree of marrow exploitation between the assemblages. Any differences manifested between the assemblages should match specific taphonomic patterning purportedly indicative of intensification resulting from observed differences in foraging efficiency. Although our results clearly show differences between the villages in diet breadth and access to high-ranked prey, specific taphonomic indicators such as cut mark frequencies, distribution, and intensity do not match the predictions generated from models of resource intensification. Contrary to predictions, differences in marrow exploitation patterns between the study villages are associated with the remains of low-ranked and common animals exploited in both areas and are not displayed by the bones of higher-ranked prey. Furthermore, the only taphonomic difference between the villages displayed by high-ranked prey consists of butchery marks not commonly recognized or reported in standard zooarchaeological analyses. We argue that although taphonomic indicators can potentially serve as proxy measures of processing effort, current expectations concerning when these attributes should reflect intensification are poorly developed and based on very limited actualistic data. Standard zooarchaeological approaches often conflate one or more taphonomic indicators as manifestations of the same process without developing expectations about the circumstances under which specific taphonomic indicators or suites of attributes might reflect intensification. Furthermore, zooarchaeological methods often fail to account for circumstances where intensification produces very similar taphonomic indicators, but is not associated with decreased foraging efficiency or resource depression (equifinality). We propose that the validity of different purported taphonomic indicators of processing effort can only be established *via* independent tests as actualistic studies. We further advance the possibility that different taphonomic indicators may be associated with different kinds of resource intensification in response to different kinds of resource scarcity. If different taphonomic indicators (or suites thereof) can be indexed to different kinds of intensification and possibly resource stress, then these data can serve as powerful interpretive tools.

## Contemporary Central African Hunters and Hunting

Observational data reported here were collected as part of an ethnoarchaeological study centered on two related groups of Bofi and Aka forest foragers in the villages of Grima and Ndele in the southwestern Central African Republic (Fig. 1). Both villages were occupied by between 100 and 150 foragers who maintained complex and multidimensional relationships with settled Bantu- and Obanguien-speaking farming populations. Although the Bofi and Aka are ethnolinguistically distinct, they claim a close ancestry and share a large number of material and cultural traits. The Bofi and Aka use the same range of hunting and processing technologies, target the same range of prey, butcher and process animals in a nearly identical manner, and generally follow the same meat-sharing rules. Various aspects of Bofi and Aka ecology are previously described in the published literature (Lupo 2011; Lupo and Schmitt 2004,



**Fig. 1** Locations of the villages of Grima and Ndele in the southwestern Central African Republic

2005; Schmitt and Lupo 2008); here, we discuss issues relevant to the ecological setting and its influence on the hunting economics in two study villages.

The factors influencing the availability of prey in this area are complex, and a complete discussion is beyond the scope of this paper, but include (1) habitat availability, density, distribution, and disturbance (Newing 2001); (2) overexploitation associated with local overhunting and the bushmeat market (Wilkie and Curran 1991); (3) proximity to main roads and market towns (Laurance *et al.* 2008; also see Wilkie *et al.* 1992); and (4) human population density and age of settlement (Vickers 1988; Redford and Robinson 1987). Of these, differences in habitat distribution and the presence of a main road are the most obvious factors distinguishing the villages. Both study villages are located in the Ngotto Forest Reserve, an area classified as a dry Guinea–Congolian rainforest (White 1983) comprising a heterogeneous mixture of wet savannas, wetlands, and semi-deciduous forests. Although there are no differences in the vegetational zones surrounding the villages, more wet savannas are located within a 1-km radius of Grima in comparison to Ndele. Closed forests, which are favorable habitats for frugivorous smaller-sized duikers (see Newing 2001), are found within 5-km walking distance from Grima. Another marked difference between the villages was the presence of a maintained dirt road that bisected Grima and served as the main artery for vehicles passing through the northern portion of the forest. Vehicles, including large trucks en route to larger towns, passed along this road several times a week. The presence of roads such as these can significantly influence the behavior patterns of prey (Laurance *et al.* 2008) and can increase access for commercial and local hunters, resulting in hunting pressure or overexploitation (Wilkie *et al.* 1992, 2000, 2005). In contrast, Ndele is remote and can only be reached by walking 53 km through the forest on a narrow footpath.

### Village Effects and Variability in Hunting Economics

Data on the hunting economics of foragers in both villages were collected over a 218-day period spanning two wet and dry seasons. Hunting technologies used in both villages are broadly divided into two groups: communal and individual. The only communal hunt practiced in this area is the net hunt, which consists of hunting groups comprising men, women, and children (see Lupo and Schmitt 2002). Individual hunting technologies are those practiced by one or more (usually related) individuals and can include hand capture and the use of spears, snares, traps, and bow and arrow.<sup>1</sup> Previously published analyses of hunting data show that there are significant differences in the profitability of using different hunting technologies (communal *versus* individual; Table 1; after Lupo and Schmitt 2004, 2005). Here, we examine differences in the availability of different kinds of prey between the two study villages using general measures of hunting profitability and prey switching for different hunting activities. These data suggest higher encounter rates with high-ranked prey and overall greater availability of animals near Ndele in comparison to Grima.

<sup>1</sup> Occasionally, foragers are hired to hunt using guns owned by farmers. With one exception, no foragers in this study owned guns or used them regularly.

**Table 1** Average post-encounter return rates for different prey taken by the Bofi and Aka (after Lupo and Schmitt 2005)

Hunting technology	Target prey <sup>a</sup>	Body weight range (kg) <sup>b</sup>	N <sup>c</sup>	Post-encounter return rate
Nets (Grima)	Small duikers	3.5–9.4	42	106
Nets (Ndele)	Small duikers	3.5–9.4	43	215
Spears	Medium duikers	15–24	15	6,769
	Small duikers	3.5–9.4	13	3,044
	Brush-tailed porcupine	1.5–4	8	2,152
Snares	Various	–	18	4,909
Hand	Giant pouched rat	1–1.4	30	561
Hand <sup>d</sup>	Various	–	15	352–5,543
Traps	Brush-tailed porcupine	1.4–4	10	1,037
Traps	Murid rats and mice	0.025–0.065	11	10

<sup>a</sup> The animal most often caught with the technology

<sup>b</sup> Values reflect average live weight range for prey as recorded by our own field observations and from Kingdon (1997)

<sup>c</sup> Number of observations

<sup>d</sup> Prey that is caught by hand (excluding giant pouched rats), which include small birds, tortoises, bats, civets, and pangolins

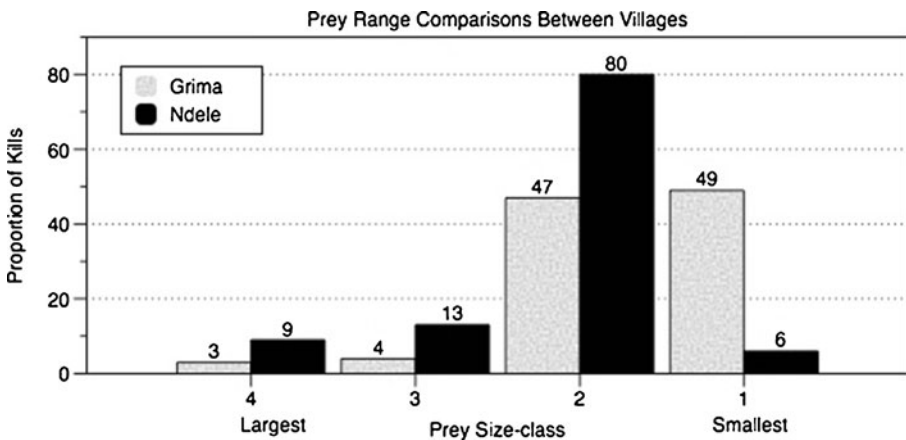
Table 2 shows the frequency of common prey taken in both villages based on observations taken during the study. The frequency of different prey taken by hunters significantly differs between the villages ( $\chi^2=865.75$ ,  $df=13$ ,  $p<0.0001$ ). The differences between the villages are more robust when these data are resorted by animal size class (Fig. 2). Grima hunters take more smaller-sized game (<2 kg) by hand capture, especially giant pouched rats, than the hunters in Ndele. Hunters in Ndele rarely pursue giant pouched rats and take more medium- and large-sized duikers using spears than the hunters in Grima. Differences in the frequencies of acquired prey are further manifested in measures of species richness and evenness. Richness is simply  $\sum TAXA$  or the number of taxa acquired. Evenness is represented by a reciprocal of Simpson's index  $1/\sum pi^2$ , where  $pi$  represents the proportion of individuals in the total site aggregate that fall in species  $i$  (Cruz-Uribe 1988; Grayson 1984; Schmitt and Lupo 1995). Because these data represent observations of the number of acquired animals, richness and evenness values are based on the number of individual carcasses captured using all hunting techniques in each village. Only small differences exist between the villages in taxonomic richness (Grima=15, Ndele=12), but evenness values reflect differences in the acquisition of different prey. Hunters in Grima generally acquired a more even range of prey (3.76) than those in Ndele, who took a less even range of species, with duikers (especially blue duikers) predominating the prey taken (1.73). Thus, evenness and richness values conform to expectations from the encounter-contingent prey choice model (PCM). In locations such as Grima, where high-ranked prey are less available, the targeted range of animals is broad and even. Ndele has more abundant high-ranking prey and the target prey range is less broad and more uneven.

**Table 2** Target prey and live weight range of prey caught in Grima and Ndele between 1999 and 2003 (wet and dry seasons combined) based on 119 and 99 days of field observations, respectively (also see Lupo and Schmitt 2005)

Taxon	Live weight range (kg) <sup>a</sup>	Size class	Grima	Ndele
Red river hog ( <i>Potamochoerus porcus</i> )	45–115	4	0	1
Yellow-backed duiker ( <i>Cephalophus silvicultor</i> )	45–80	4	1	2
Bay or Peters duiker ( <i>C. dorsalis</i> or <i>callipygus</i> )	15–24	3	19	42
Civet ( <i>Civettictus civetta</i> )	7–20	2	2	1
Blue duiker ( <i>C. monticola</i> )	3.5–9.4	2	112	242
Mongoose (Herpestidae)	–	–	1	1
Monkey ( <i>Cercopithecus</i> sp.)	1.8–6	2	11	10
Brush-tailed porcupine ( <i>Atherurus africanus</i> )	1.4–4	1	34	11
Tree pangolin ( <i>Phataginus tricuspis</i> )	1.6–3	1	6	0
Tortoise ( <i>Kinixys</i> sp.)	1–2	1	4	3
Giant pouched rats ( <i>Cricetomys emini</i> )	1–1.4	1	111	7
Murid rats and mice (Muridae)	0.025–0.065	1	10	1
Bats	0.010–0.015	1	2	0
Birds (various species)	–	–	3	3
Snake (unidentified)	–	–	1	0

<sup>a</sup> Live weights after Kingdon (1997)

Additional measures of hunting economics in Ndele suggest overall high productivity, as measured by the abundances of high-ranked prey. All of the hunters in Ndele ( $n=33$ ), regardless of hunting technology, have a significantly higher daily mean encounter rate with prey (of any kind) in comparison to hunters in Grima ( $n=36$ ; 8.75 versus 5.04 animals per hunt, respectively;  $t$  test=3.217,  $p=0.0010$ ). Differences in the prey encounter rates result in differences in hunting success, as measured by the number of successful hunts divided by the number of days spent hunting by each



**Fig. 2** Prey range comparisons between villages



man. Overall, hunters in Ndele are significantly more successful than those in Grima, regardless of the hunting technology they used (0.530 and 0.290, respectively,  $t$  test=3.29,  $p=0.0009$ ).

### Net Hunting and Prey Switching

Although net hunting is practiced in both villages, net hunters in Ndele have significantly higher mean success rates as measured by the proportion of successful hunts (0.554 *versus* 0.271, respectively;  $t$  test=5.069,  $p<0.0001$ ). Similarly, Ndele hunters achieve a significantly higher mean post-encounter return rate from net hunting than hunters in Grima (215.42 *versus* 106.87 kcal/h, respectively;  $t$  test=2.366,  $p<0.05$ ). Even so, net hunting has dramatically lower post-encounter return rates compared to most other hunting opportunities in both villages (Table 3; see also Lupo and Schmitt 2005). Following the logic of the PCM, hunters should cease net hunting to pursue higher-ranking prey whenever they are encountered. During any single net hunt, individuals can (and do) pursue other hunting and foraging activities. It is very common for individual hunters to break away from the net-hunting group to pursue an animal individually. While it was impossible to follow every participant in the net hunt, we collected information on the hunting technology used to acquire different kinds of prey and the frequency of different animals obtained during each hunt. As measured by the mean number of prey taken with other technology outside the nets, Grima hunters abandoned net hunts in favor of other opportunities significantly more often than Ndele hunters (two-tailed test:  $t$  test=1.74,  $p=0.084$ ). But more revealing differences between the villages are shown by the frequencies of different hunting opportunities that precipitate the abandonment of a net hunt (Table 3). Grima hunters broke away from net hunts to pursue prey by hand significantly more often than hunters in Ndele (two-tailed test:  $t$  test=4.26,  $p=0.00005$ ), and a high proportion (0.82) of those captures targeted giant pouched rats. Conversely, Ndele net hunters rarely broke off net hunts to pursue small-sized prey *via* hand capture, and hunters were significantly more likely to discontinue net hunts in favor of pursuing prey with spears than those in Grima (two-tailed test:  $t$  test=2.19,  $p=0.03$ ). Of the speared animals acquired by the Ndele hunters, almost half (0.44) were large- and medium-sized duikers. In contrast, Grima hunters broke away from net hunts to pursue individual prey with spears far less often (0.13), and of those prey dispatched with spears, only a small proportion (0.18) were large- to medium-sized duikers.

**Table 3** Tallies of prey captured during net hunts with different technologies

Village	No. of net hunts	Total prey	No. captured in nets ( $N$ )	No. captured by hand	No. speared	Other
Grima <sup>a</sup>	45	173	92	56	22	3
Ndele	43	280	221	9	42	8

<sup>a</sup> The number of net hunts observed in Grima reported here is higher than the number reported in Table 1. Three additional hunts are reported here, but were not included in determining return rates; although we were able to record the prey taken, we were not sure how many people actually participated in the hunt

## Duiker Mortality Profiles

To further investigate possible differences between the villages in the overall availability of prey, we compared the age profiles of blue and medium-large-sized duikers taken by hunters. In animals unsusceptible to behavioral depression and characterized by discrete breeding areas, prey overexploitation can decrease the mean and maximum age of exploited specimens (Broughton 2002). This follows because (1) hunters will sometimes preferentially target larger-sized and older individuals with higher returns over younger, smaller-sized individuals; (2) as mortality increases, even if it is unbiased, intraspecific competition will decrease and increase the recruitment of juvenile specimens; and (3) increased mortality leads to a decreased probability of surviving into adulthood as the average life span decreases (Broughton 2002).

To access the age profiles, 209 blue duiker and 81 medium- and large-sized duiker demi-mandibles were assigned to age categories based on the eruption of permanent teeth developed by Dubost (1980) for living populations. Some of these same mandibles are included in the meal assemblages described below, and other specimens came from household midden assemblages collected in Grima and Ndele and are described elsewhere (see Lupo and Schmitt 2005). Comparisons of the frequencies of the different specimens in different age categories (Table 4) show that the age distributions of duikers in both villages do not significantly differ from those found in wild populations. However, when all subadult categories are combined and compared to the adult specimens, subadults are significantly more abundant in Grima than in Ndele ( $\chi^2=11.06$ ,  $p=0.0008$ ), which suggests a lower mean age of capture for this animal in Grima. A similar comparison for medium- and large-sized duikers shows no significant differences in the abundance of subadults between the villages. Additional and potentially significant differences between the villages include the presence of highly worn third and second molars on adult blue and medium- and large-sized duiker specimens. Approximately 40 % of the adult blue duiker

**Table 4** Mortality profiles derived from mandible tooth eruption sequences for Grima and Ndele Duikers

Age classes	Wild blue duiker (Dubost 1980)	Grima blue duiker <sup>a</sup>	Grima M/L duiker <sup>b</sup>	Ndele blue duiker	Ndele M/L duiker <sup>b</sup>
M0: 0–4 months	3	1	3	1	1
M1: 4–10 months	9	3	1	2	5
M2: 10–20 months	19	16	2	8	18
Subadult: 20–28 months <sup>c</sup>	15	48	1	37	13
Adult: >28 months <sup>d</sup>	53	33	5	60	32

<sup>a</sup> Values for Grima and Ndele are demi-mandible counts (NISP) for those specimens that retained teeth

<sup>b</sup> M/L duiker are combined counts of medium- and large-sized duikers. Here, we assume that tooth eruption sequences for blue duikers are close approximations for all medium- and larger-sized duikers

<sup>c</sup> Specimens with partially erupted third molars

<sup>d</sup> Specimens with complete adult dentition

specimens and 18 % of the medium- and large-sized duiker specimens in Ndele display heavily worn second and third molars. In contrast, none of the adult specimens in Grima displayed heavy wear patterns. These data could indicate that older animals were being taken in Ndele than in Grima, but tooth wear patterns may also vary as a function of the range resources an animal consumes. However, if there were real differences between the villages in the resources being consumed by prey, we would expect differential tooth wear to be more widespread among duiker specimens in the Ndele assemblages.

By several different measures, prey are generally less abundant, and medium- to large-sized and high-ranked prey are encountered less frequently by Grima hunters than those in Ndele. The age profiles also indicate a lower mean age of capture for blue duikers in Grima, suggestive of overexploitation for this species. Although we cannot directly demonstrate that the foragers in Grima were under resource stress, field observations and the quantitative data presented here indicate depressed foraging efficiency in comparison to Ndele. Furthermore, some of the classic markers associated with depressed foraging efficiency, such as expanded diet breadth, are evident in the hunting patterns of the Grima population.

### **Taphonomic Analyses: Materials and Methods**

Between 1999 and 2002, animal bones were collected from every forager in our sample after each evening meal (so-called meal assemblages). These were originally collected to monitor prey consumption and food sharing among households (see Lupo and Schmitt 2004, 2005), but the assemblages also provide an unparalleled inter-village comparison of taphonomic damage. Every day, each person in our sample (including children) was given a plastic bag labeled with their name and the date and asked to place everything they did not eat into the bags.<sup>2</sup> Each day, the bags were collected and the contents cleaned with water and detergent, sundried, and immediately repackaged for transport. Thus, the assemblages consist of animal remains that were not exposed to noncultural taphonomic processes. The bones were transported to the Zooarchaeological Laboratory at Washington State University where they were analyzed by one of us (see Fancher 2009). All taphonomic damage was identified macroscopically with the aid of bright light and a small  $\times 10$  hand lens. The anatomical locations of tool marks were recorded using standard codes or, when necessary, new codes were defined and illustrated (Fancher 2009: Appendix A). Because multiple marks can occur on the same bone specimen, we recorded both the number of tool-marked specimens and the total number of distinct marks. Distinct marks were those that appeared to be the result of a separate tool stroke; two parallel striations less than a millimeter apart were counted as one mark, whereas striations that were farther apart and/or oriented differently were counted as separate marks.

The Bofi and Aka butcher most prey with metal knives and machetes, creating three different classes of tool mark: cut marks, chop marks, and partial chop marks.

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<sup>2</sup> Importantly, we did not instruct the participants on how to treat the bones. We did not request that they avoid chewing, modifying, or damaging the animal bones during acquisition, processing, or consumption. Our instructions were simply “give us what you do not eat.”

Cut marks are produced by drawing a blade across bone surfaces and were identified based on established morphological criteria (e.g., Lyman 1994). Chop marks, or “complete chops,” pass through the bones of the small fauna discussed here, leaving planar surfaces or shear faces. Partial chops are comparable to hack marks or cleave marks (Gifford-Gonzalez 1989). Cleave marks are produced by striking bone surfaces with a blade at a perpendicular angle and are wider and deeper than cut marks, often with bone fragments being crushed inward as a result of percussive force (Potts and Shipman 1981, p. 577). Observations show that Bofi and Aka create chop and partial chop marks when animal parts are partitioned to share or distribute to others and/or to fit into metal cooking pots as part of stew manufacturing (e.g., Fancher 2009; Lupo and Schmitt 1997).

Table 5 shows the taxonomic composition of the number of identifiable specimens (NISP) from the meal assemblages for both villages. Note that the abundances of prey in different size classes in the meal assemblages parallel the observed differences in the frequencies of prey acquisition (Fig. 3). The most revealing differences are illustrated by the relative abundance of Bay/Peters duiker, blue duiker, pouched rat, and mouse. Bay/Peters and blue duiker combined account for over 83 % of Ndele NISP, whereas pouched rat and mouse are rare and absent, respectively. In Grima, pouched rat and mouse contribute nearly 40 % of assemblage NISP. These data suggest a proportionally greater emphasis on the lowest ranking (and smallest sized) taxa in Grima.

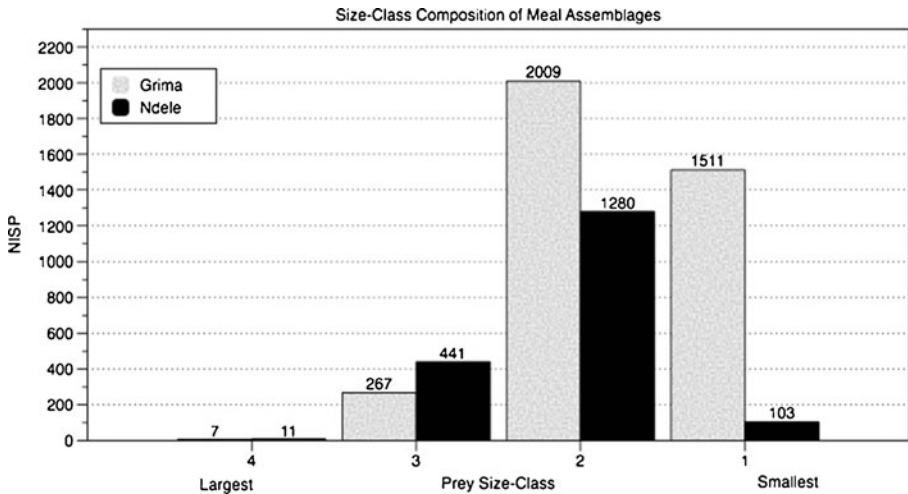
Taphonomic patterning displayed by the bones in these meal assemblages is used to test the following expectations. The null hypothesis is that there are no differences

**Table 5** Taxonomic composition, NISP, and butcher-marked NISP of meal assemblages collected in Grima and Ndele between 1999 and 2002

Taxon	Grima NISP	Grima NISP CM	Grima NISP M	Ndele NISP	Ndele NISP CM	Ndele NISP M
Red River hog	0	0 (0)	0 (0)	11	5 (45.5)	8 (72.7)
Yellow-backed Duiker	7	4 (57.1)	5 (71.4)	0	0 (0)	0 (0)
Bay or Peters duiker	267	89 (33.3)	183 (68.5)	441	144 (32.7)	260 (59.0)
Civet	15	6 (40.0)	6 (40.0)	0	0 (0)	0 (0)
Blue duiker	1,507	377 (25.0)	856 (56.8)	1,084	273 (25.2)	626 (57.8)
Monkey	54	6 (11.1)	21 (38.9)	10	3 (30.0)	7 (70.0)
Porcupine	305	34 (11.1)	105 (34.4)	120	14 (11.7)	20 (16.7)
Pangolin	75	10 (13.3)	34 (45.3)	0	0 (0)	0 (0)
Tortoise	53	0 (0)	2 (3.8)	66	2 (3.0)	5 (7.6)
Giant pouched rat	1,135	84 (7.4)	137 (12.1)	103	20 (19.4)	38 (37.3)
Murid rats and mice	376	3 (0.8)	3 (0.8)	0	0 (0)	0 (0)
Totals	3,794	613 (16.2)	1,352 (35.6)	1,835	461 (25.1)	964 (52.5)

Values in parentheses are the percentages of NISP with CM and M

*NISP CM* number of specimens that display one or more cut marks (incisions) of any kind, *NISP M* number of specimens displaying a tool mark of any kind (excluding impact-related marks), including incisions and chops



**Fig. 3** Size class composition of meal assemblages

in the frequency or nature of taphonomic indicators between the two study villages. If the forager occupants of Grima are intensifying their use of prey, we expect the differences between the assemblages to be manifested in specific ways following the prey and patch choice models. Specifically, if the overall foraging efficiency is depressed due to reduced environmental productivity in Grima, we expect:

1. Evidence of greater processing effort manifested in all prey and reflected by a high frequency of butchery marks (of any kind)
2. Marked differences in processing effort in the remains of prey that are undergoing exploitation depression and are common to both study villages (i.e., blue duiker)
3. High frequencies of butchery marks reflecting high levels of processing effort and resource partitioning among camp occupants on the remains of higher-ranked prey
4. Nonselective distribution of butchery marks across the skeleton of high-ranked and common prey, including low-value parts
5. Greater investment in extracting within bone products (e.g., marrow) as reflected by bone fragmentation patterns for high-ranked and common prey
6. Marrow removal from low-value parts, such as mandibles and metapodials, for high-ranked and common prey

### **Results: Butchering Mark Abundances and Intensity**

Here, we consider the abundances and intensity of cut marks and other evidence of processing as measured by the NISP and specimen counts (Abe *et al.* 2002, p. 645). NISP- level counts (raw or proportional values) are widely reported in archaeological contexts, but may underestimate processing effort because specimens are only identified as “cut” or “not cut” regardless of the number of distinct marks displayed by the specimen. Specimen counts are the number of marks displayed per bone specimen and are less often reported by analysts, but these counts may provide a better measure

of butchering effort if processing effort is linked to mark production. In this analysis, specimen-based marks are referred to as mark intensity. Because most existing analyses focus solely on cut marks, we distinguish between the frequencies of cut marks (hereafter CM) and butchery marks (hereafter M). The former only includes incisions, while the latter is more inclusive and counts all tool marks (cut marks, chops, and partial chops). It does not include damage such as human tooth marks (see Landt 2007) or impact notches aimed solely at removing marrow.

Based on the NISP counts, the frequencies of butchery marks significantly differ between the Grima and Ndele meal assemblages (CM+/-:  $\chi^2=145.85$ ,  $df=1$ ,  $p<0.005$ ; M+/-:  $\chi^2=64.39$ ,  $df=1$ ,  $p<0.005$ ).<sup>3</sup> However, this result is largely driven by the greater number giant pouched rats in the Grima collection that display marks. When these specimens are excluded from the analysis, there are no significant differences in CM or M frequencies between the villages (CM+/-:  $\chi^2=2.86$ ,  $df=1$ ,  $p=0.09$ ; M+/-:  $\chi^2=0.055$ ,  $df=1$ ,  $p=0.81$ ). Specimen level counts or mark intensity, as measured by the mean number of CM or M displayed by all taxonomically identifiable specimens in the assemblages, are also very similar and do not significantly differ (Mann–Whitney  $U$  test: CM,  $U=26$ ; M,  $U=25$ ). Thus, on an assemblage level, there are no appreciable differences in the frequency or intensity of marks between the villages.

When only the remains of blue duikers are compared between the villages, there are no significant differences in the frequencies of CM or M (CM+/-:  $\chi^2=0.059$ ,  $df=1$ ,  $p>0.10$ ; M+/-:  $\chi^2=0.7215$ ,  $p=0.3957$ ) based on NISP counts. Comparisons of mark intensity (as measured by mean CM and M displayed by all specimens of blue duiker remains) between Ndele and Grima are also similar (Mann–Whitney  $U$  test: CM,  $U=18$ ; M,  $U=17$ ).

For large-sized and high-ranked prey, there are no significant differences between the villages in CM frequencies based on NISP counts (CM+/-:  $\chi^2=0.073$ ,  $df=1$ ,  $p=0.78$ ). There are, however, significant differences when all butchery marks (M) are considered in the frequencies for combined counts of large- and medium-sized duikers (M+/-:  $\chi^2=6.34$ ,  $df=1$ ,  $p=0.011$ ). Large-bodied prey remains from Grima display more marks, especially chops, resulting from portioning body segments into shares and pot-sized pieces than in the Ndele collections. But when mark intensity is examined, there are no significant differences in the mean number of CM or M displayed by specimens of medium- and large-sized game between the villages (Mann–Whitney  $U$  test: CM,  $U=13$ ; M,  $U=17$ ).

### Cut and Butchery Mark Distribution

Assemblage-level NISP or specimen counts may be too gross to reveal important differences in part treatment. Table 6 shows the proportion NISP that display cut and butchery marks for the different body segments of medium and large duikers and blue duikers. Although smaller-sized prey, notably giant pouched rats, display tool marks, these prey are generally too small to be subjected to extensive filleting or meat

<sup>3</sup> Parametric tests are not used here because damage counts in the largest available datasets are not normally distributed (Capaldo 1995).

**Table 6** Total NISP and butchery marks by body segment for blue duikers and medium/large duikers in the Grima and Ndele assemblages

Body segment	Blue duiker			Medium/large duiker		
	NISP	NISP CM	NISP M	NISP	NISP CM	NISP M
Grima village						
High-value parts						
Cranium/mandible	221	40 (18.1)	67 (30.3)	30	10 (33.3)	11 (36.7)
Cervical verts.	111	28 (25.2)	69 (62.2)	41	7 (17.1)	36 (87.8)
Thoracic verts.	183	23 (12.6)	150 (82.0)	42	9 (21.4)	41 (97.6)
Lumbar verts.	113	36 (31.9)	105 (93.0)	14	6 (42.9)	12 (85.7)
Ribs/sternum	375	118 (31.5)	238 (63.5)	74	37 (50.0)	53 (71.6)
Innominate/sacrum	75	33 (44.0)	65 (86.7)	8	4 (50.0)	7 (87.5)
Femur	45	24 (53.3)	33 (73.3)	5	3 (60.0)	5 (100)
Low-value parts						
Scapula	37	12 (32.4)	15 (40.5)	1	0 (0)	0 (0)
Humerus	48	22 (45.8)	32 (66.7)	3	0 (0)	1 (33.3)
Radius/ulna	65	12 (18.5)	17 (26.2)	12	2 (16.7)	6 (50.0)
Tibia	70	21 (30.0)	33 (47.1)	14	7 (50.0)	7 (50.0)
Ndele village						
High-value parts						
Cranium/mandible	256	76 (29.7)	87 (34.0)	155	59 (38.1)	77 (49.7)
Cervical verts.	81	17 (21.0)	58 (71.6)	45	5 (11.1)	28 (62.2)
Thoracic verts.	112	8 (7.1)	94 (83.9)	55	14 (25.4)	48 (87.3)
Lumbar verts.	70	17 (24.3)	66 (94.3)	15	6 (40.0)	14 (93.3)
Ribs/sternum	228	60 (26.3)	159 (69.7)	64	41 (64.1)	53 (82.8)
Innominate/sacrum	52	18 (34.6)	39 (75)	17	4 (23.5)	14 (82.4)
Femur	61	25 (41.0)	43 (70.5)	12	4 (33.3)	7 (58.3)
Low-value parts						
Scapula	29	13 (44.8)	19 (65.5)	3	1 (33.3)	2 (66.7)
Humerus	33	14 (42.4)	23 (69.7)	3	2 (66.7)	2 (66.7)
Radius/ulna	48	9 (18.8)	15 (31.3)	4	1 (25.0)	1 (25.0)
Tibia	28	9 (32.1)	15 (53.6)	10	3 (30.0)	4 (40.0)

Values in parentheses are the percentage of NISP that display butchery marks

removal and are expected to show little skeletal variation in butchery mark distribution or intensity. Therefore, we conducted a detailed analysis examining the relationship between CM and M frequency and measures of skeletal part value for blue and medium- and large-sized duiker. If the occupants of Grima are experiencing reduced foraging efficiency, low-value skeletal parts should display more butchery marks in this assemblage in comparison to Ndele. Part value is given by the Food Utility Index (FUI; after Metcalfe and Jones 1988) which measures the gross food value of different skeletal parts and is found by subtracting the dry bone from the total part

weight (i.e., fully fleshed and intact). FUI values for blue duikers were obtained by butchering experiments conducted on a single male blue duiker in 1999 (see Appendix 1). Although similar experiments were not conducted on medium- or larger-sized duikers, we assume that the FUI for blue duikers provides a reasonable estimate for the relative distribution of tissue for all duikers. In this analysis, NISP and specimen-level counts of CM and M are combined for all high- and low-value parts. High-value parts include thoracic vertebrae, ribs, femur, cranium, lumbar, innominate, and cervical vertebrae. Low-value parts include the scapula, tibia, humerus, and radius. Metapodials and phalanges were excluded because these parts only yield small amounts of marrow and fat and, with the exception of the metapodials (discussed further below), are undamaged.

Comparisons of the frequencies of CM and M for combined counts of high- and low-value parts for blue and medium- and large-sized duikers are not significantly different, save for one exception. High-value body parts of medium- and large-sized duikers in Grima display significantly more marks (of any kind) than those in Ndele ( $M+/-$ :  $\chi^2=11.18$ ,  $df=1$ ,  $p=0.0008$ ). This mirrors our results above based on NISP-level counts. The same analyses were performed on mark intensity. Comparisons of combined counts of low-value parts show that mark intensity does not significantly vary between Grima and Ndele. Both assemblages show nearly identical values for cut mark intensity for low-value parts, but significantly more marks occur on high-value parts of medium and large duikers in the Grima assemblage than in Ndele ( $\chi^2=3.93$ ,  $df=1$ ,  $p=0.047$ ).

In summary, comparative analyses of the distributions of CM and M show that few differences occur between the two village assemblages. The remains of medium- and large-sized duikers in Grima show a biased distribution of butchery marks (notably chops and partial chops) on high-value parts resulting from partitioning the skeletal part into smaller portions. Because butchering and cooking technology and population size are very similar between the two villages, this could reflect a higher degree of sharing of a highly prized resource (Table 6).

## Bone Fragmentation and Marrow Extraction

Zooarchaeological studies often use the extent and/or intensity of bone fragmentation to evaluate the intensification of resource use within an assemblage (Broughton 1999; Grayson and Delpech 2003; Munro and Bar-Oz 2005; Nagaoka 2005, 2006; Outram 2001; Quirt-Booth and Cruz-Urbe 1997; Todd and Rapson 1988; Wolverson 2005). Following Munro (2004), the extent of fragmentation can be measured by the overall proportion of complete elements in assemblages, and the intensity of fragmentation is often found by calculating the ratios of NISP to the minimum number of elements (see Lyman 1994). We do not expect evidence for high-intensity bone fragmentation in these assemblages because our field observations show that bones are not highly comminuted to extract grease or during meat consumption. Most of the meal assemblages consist of minimally broken specimens and, in some cases, nearly complete bone portions (Table 7). In fact, comparisons between the overall degree of bone fragmentation for blue duikers and medium/large-sized duikers in the two villages reveal no significant differences in the number of elements that are broken



**Table 7** NISP and complete NISP of marrow-bearing bones for blue and medium/large duiker in Grima and Ndele assemblages

Marrow-bearing part	Blue duiker		Medium/large duiker	
	NISP	NISP complete	NISP	NISP complete
Grima village				
Mandible	57	49 (86.0)	16	11 (68.8)
Humerus	45	13 (28.9)	3	2 (66.7)
Radius	32	10 (31.3)	4	1 (25.0)
Metacarpal	17	7 (41.2)	1	1 (100)
Femur	39	4 (10.3)	5	0 (0)
Tibia	69	7 (10.1)	11	1 (9.1)
Metatarsal	31	11 (35.5)	2	0 (0)
Total	290	101 (34.8)	42	16 (38.1)
Ndele village				
Mandible	81	74 (91.3)	64	47 (73.4)
Humerus	33	2 (6.1)	3	2 (66.7)
Radius	24	12 (50.0)	2	1 (50.0)
Metacarpal	3	1 (33.0)	4	4 (100)
Femur	54	3 (5.6)	6	0 (0)
Tibia	24	2 (8.3)	4	1 (25.0)
Metatarsal	10	8 (80.0)	1	1 (100)
Total	229	102 (44.5)	84	56 (66.7)

Values in parentheses are the percent NISP complete

(broken+/-: blue duiker,  $\chi^2=2.63$ ,  $df=1$ ,  $p=0.104$ ; medium and large duiker,  $\chi^2=0.52$ ,  $df=1$ ,  $p=0.468$ ).

Another important line of evidence of intensification is the selective exploitation of low-value marrow-bearing bones. A variety of different measures can be used to examine the degree of bone fragmentation for major marrow-bearing bones. For instance, evaluation of the degree of marrow extraction for large artiodactyls often relies on limb bone shaft-to-end ratios (see Broughton 1999; Grayson and Delpech 2003), but the small body size of the prey in the Grima and Ndele samples precludes the use of those measures in this analysis. Marrow is often consumed as part of the meal, but marrow cavities of limb bones are only incidentally breached during stew manufacturing. Occasionally, marrow is also extracted from prey limb bones by removing limb ends, usually by hand or simply biting the portion off. Here, we use the proportion of complete to incomplete bones to evaluate differences in the extent of marrow exploitation between the villages. Comparison of the number of blue duiker complete to incomplete marrow-bearing bones is significantly different between the villages ( $\chi^2=5.069$ ,  $df=1$ ,  $p=0.023$ ) as Grima has fewer complete and more incomplete marrow-bearing bones than Ndele, which could indicate a greater focus on marrow extraction for blue duikers.

Although precise measures of the amount of marrow found in duiker bones are unavailable, experimental studies conducted on African fauna of different sizes show that the mandible, radius, metacarpal, and metatarsal consistently yield low amounts of marrow in comparison to the rest of the limb bones (Lupo 1994). If only low-yielding marrow bones are considered, the numbers of complete and incomplete bones for blue duiker are significantly different between the villages ( $\chi^2=17.56$ ,  $df=1$ ,  $p=0.00004$ ). Ndele contains a higher number of complete and unbroken low-yielding marrow parts for blue duikers than Grima. Almost all of the high-yielding marrow-bearing bones (i.e., humerus, femur, and tibia) are broken in both assemblages. But contrary to predictions, the Grima assemblage has a significantly higher number of complete and unbroken high-marrow-bearing bones than Ndele ( $\chi^2=5.45$ ,  $df=1$ ,  $p=0.019$ ). The same set of analyses was conducted for medium- and large-sized duikers and revealed moderately significant differences in the number of complete and incomplete low-yielding marrow bones between the assemblages ( $\chi^2=2.72$ ,  $df=1$ ,  $p=0.09$ ). More low-yielding marrow-bearing bones of medium and large duikers are broken in the Grima assemblage in comparison to Ndele, while the number of complete and incomplete high-yielding marrow bones for medium and large duikers does not significantly differ between the villages ( $\chi^2=0.268$ ,  $df=1$ ,  $p=0.603$ ).

Of the analyses conducted here, only marrow exploitation of low-value parts for blue duikers is robustly indicated. A seemingly contrary result for blue duikers in Grima is the relatively high abundance of nearly complete high-yielding marrow bones. However, if as our previous analysis suggests the mean age of blue duikers taken by Grima hunters is lower than those taken by Ndele hunters, then differential exploitation of high-marrow-bearing bones may be a response to fat-depleted marrow in younger animals. This is further supported by the fact that the Grima meal assemblages contain a significantly higher frequency of immature blue duiker bones (as measured by NISP) than the Ndele assemblages ( $\chi^2=8.89$ ,  $p=0.0028$ ). Alternately, differential fragmentation of low- and high-yielding marrow bones could indicate nutritional stress in blue duiker populations near Grima. The sequence of marrow fat mobilization is well known; proximal limb bones mobilize fat first, followed by the lower limbs (e.g., Speth 1987, 1989). Lower limbs and mandibles act as reservoirs for marrow fat as the animal undergoes stress. There are no data indicating that blue duikers living near Grima were nutritionally stressed, but recall that more open wet savannas surround Grima in comparison to Ndele. Small-sized duikers, such as the blue duiker, thrive on large quantities of small-sized but high-quality arboreal fruit which they find on the forest floor. Some of the highest densities of blue duikers in the world are found in forests with abundant fruiting trees and monkeys, with the latter species providing windfalls of fallen fruit to the duikers (Kingdon 1997). In contrast, medium- and larger-sized duikers, while adapted to forest habitats and frugivorous, have anatomical features such as a larger jaw size and more robust masticatory musculature (Newing 2001). Larger-bodied duikers can efficiently process larger quantities of different kinds of plant foods and can tolerate more poor quality forage in their diets than blue duikers (Newing 2001). Because small- and medium/large-sized duikers have differences in the amount of poor quality foods that they can tolerate, the onset of markers of physiological stress as a result of habitat depletion may be different for these groups. Specifically, blue duikers are

likely to quickly physiological respond to the decreased abundances of high-quality fruit than medium- and larger-sized duikers.

## Discussion

This study is the first to match independent observations of reduced foraging efficiency, increased diet breadth, and the depressed availability of high-ranked prey with taphonomic analyses of faunal assemblages. The results of the comparative analyses of the two Central African villages are mixed and the taphonomic differences between the assemblages are unanticipated from previous studies. Notably, the remains of high-ranked (and large-bodied) prey associated with Grima displayed none of the standard taphonomic indicators for intensification. High-ranking and large-bodied prey displayed differences in the frequency of butchery marks (broadly defined here to include chop marks), which were selectively distributed on high-value body parts. This damage was inflicted when parts were partitioned during consumptive processing and reflects the creation of segments for distribution among camp occupants. Conversely, the remains of blue duikers, which are considerably smaller in body size and lower in return rate, showed selective fragmentation of low-yielding marrow bones.

One obvious explanation for these results might be that prey depression in Grima is not marked enough to result in increased processing effort or be manifested by the predicted taphonomic patterns. Recall that both observational and zooarchaeological evidence show classic characteristics of reduced foraging efficiency in Grima. If these characteristics are not associated with resource intensification, then the value of these criteria for identifying the same phenomenon in zooarchaeological assemblages needs to be reevaluated (see also Bird *et al.* 2009). Furthermore, if these circumstances do not result in increased processing effort, then we might rightly ask, when does resource depression result in highly visible taphonomic indicators of increased processing effort? How great does resource depletion need to be before human processing intensity becomes a compulsory response? These questions remain unresolved, but are clearly important for establishing taphonomic attributes as indicators of processing effort.

Another possible explanation might be that taphonomic indicators are poor or ambiguous indices of processing effort. However, our results do not disprove or even derail the possibility that taphonomic attributes can be used as supplementary evidence in concert with changes in faunal abundances. Instead, we argue that these results invite a reexamination of the value of different taphonomic indicators as proxy measures of processing effort. The mismatch between predictions derived from previous studies and our observations might be explained by variability in the circumstances that manifest certain taphonomic attributes. If this is the case, perhaps the most appropriate question is, under what circumstances do we expect specific taphonomic characteristics to index processing effort?

When are Cut Mark Frequencies Good Proxy Measurements of Processing Effort?

In this analysis, cut mark frequencies were not particularly useful indices of processing effort for large-sized and high-ranked prey. As discussed in the beginning of this

paper, part of the problem with evaluating these data stems from the high degree of variability in cut mark frequencies and distribution that remains unresolved. This fact alone does not derail the use of cut marks as a proxy measure for processing effort in zooarchaeological analyses, especially when used as an adjunctive line of evidence in concert with other characteristics. However, analysts might further refine the predictive value of these taphonomic indicators by asking, when do we expect cut marks to index processing effort in larger-sized prey?

Several factors, such as the circumstances of carcass transport and preparation, mitigate against the creation of high frequencies of cut marks on animal parts in the assemblages discussed here. Among the Bofi and Aka, most game is acquired within 5 km of the village and carcasses in almost any size range (except elephants) are transported to residential camps or consumption locations intact or nearly so. Field processing effort of larger-bodied prey is limited to evisceration, skinning (which is optional), and segmenting the carcass into quarters. With the exception of very small morsels of meat that are given out in the field as gifts, meat is not stripped or filleted from the carcass. Bones from medium- and large-sized duikers are rarely processed and discarded at or near the place of acquisition.<sup>4</sup> Once transported, carcass parts are almost always immediately processed for consumption by thermal methods: stewing or roasting. Meat attached to bone is commonly stewed until the attached flesh either falls off or is easily removed by biting. The trade-off here is between spending the time carefully filleting meat from the bone with a knife or using thermal processing to do part of the work.

Binford (1978) reported that high cut mark frequencies mirrored processing effort based on his experience with the Nunamiut, which involved circumstances where one or more large-sized carcasses were synchronously acquired and butchered body parts were either stored (by freezing or drying) or the meat filleted from the bones, which were subsequently discarded in the field. A high investment in cutting flesh from the bone makes sense in this context because the attached tissue is uncooked and the bone discarded before being transported to a residential or consumption location. Parts transported to residential camps are either immediately processed for consumption with thermal technology or cached near the house for potential future use. The latter often consisted of low-value parts (metapodials and mandibles) that were used as emergency food during times of need.

Cut mark frequencies do not reflect processing effort in the Bofi and Aka assemblages because field processing effort is low and carcasses/segments are completely transported to residential camps. In contrast, Nunamiut carcass acquisition is characterized by high field processing effort of different body parts to reduce transport and storage costs. Both groups practice immediate consumption of meat and animal products *via* thermal alteration, which reduces processing effort and the use of tools during consumption. But delayed consumption *via* storage among the Nunamiut creates circumstances where frozen or dried tissues that require more effort to extract are exploited (Binford 1978, 1984).

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<sup>4</sup> Certain rare or favored kinds of prey are treated differently. For instance, carcasses of forest hogs, a favored meat, are often processed and entirely consumed in the forest by foragers in secret. Consumption in secret was a deliberate strategy to avoid sharing the meat with others or being bullied into selling or trading the meat.

From an archaeological perspective, analysts might expect cut marks to index processing intensity when field processing and selective part culling realize a large gain in reduced transport costs (e.g., Metcalfe and Barlow 1992; Lupo 2001). Under these circumstances, high frequencies of cut marks resulting from increased processing effort are most likely to occur at acquisition or field processing locations where carcasses were stripped of tissue and the parts discarded. High frequencies of cut marks are not expected on body parts that are thermally altered and immediately consumed at residential sites, but delayed consumption techniques such as freezing or drying toughen attached tissues and can subsequently require additional processing effort. Clearly, there could be other circumstances under which cut mark frequencies index processing effort, but few actualistic studies provide independent linkages of these two phenomena (but see Egeland 2003).

### What Does Increased Bone Fragmentation Mean: Resource Scarcity or Seasonal or Chronic Shortages?

In addition to understanding when specific attributes might be linked to processing effort, the recognition that some taphonomic attributes are potentially highly ambiguous indicators of intensification is equally important. High levels of bone fragmentation, for instance, are often cited as evidence of bone grease extraction, which is widely viewed as an index of resource intensification. This idea is based on anecdotal ethnographic references that cite bone grease manufacturing as an activity linked to food scarcity. Binford (1978, pp. 146–150), for instance, recalled how Nunamiut “old timers” boiled bone splinters for remnant grease when resources were scarce. Within-bone grease is the last edible product that can be removed from the bone before it is discarded, and experimental studies show that grease rendering can be associated with very high processing costs per unit of kilocalorie extracted (e.g., Binford 1978; Lupo and Schmitt 1997; Saint-Germain 1997). Processing costs not only involve an investment in time but also include fuel and other raw materials that can be difficult to find. Thus, the exploitation of bone grease qualifies as resource intensification, but, and as discussed below, it is not always associated with long-term resource scarcity.

Although bone grease can be an expensive resource to exploit, there are some very common circumstances where the immediate costs of manufacturing are offset by future benefits. A number of ethnographic and historic sources (see, e.g., Leechman 1951; Lupo and Schmitt 1997; Saint-Germain 1997) describe bone grease extraction from large-bodied animals to offset the seasonal (and very temporary) unavailability of fat and/or to augment supplies of lean meat (see Speth 1983, 1987, 2010). Animal grease had value that extended beyond consumption, and it was used for a variety of utilitarian purposes (e.g., lubricant, skin conditioner, etc). Bone grease is a highly storable product that has a shelf life spanning months. In areas with seasonal shortages of animal fat, the time spent rendering grease during seasons of plenty is offset by future benefits that were realized months later. Ironically, historic descriptions often show that bone grease manufacturing took place opportunistically when large numbers of animals were procured (Weltfish 1965). Under these circumstances, an economy of scale prevailed to lower the cost per unit of kilocalorie. Thus, seasonal processing of bone grease qualifies as a form of intensification, but is not usually the result of chronic resource depression. Given its widespread and common use among

contemporary and historic peoples, the exploitation of bone grease cannot always be viewed as a marker for chronic resource stress

Yet, there are well-known and anecdotal instances where extensive bone fragmentation resulting from anthropogenic activities does reflect intensification resulting from chronic resource scarcity. Probably the best-known case is reported by Gould (1996) who describes how ethnographic and historic aboriginal populations in the Western Desert of Australia smashed or pounded prey bones into small fragments during consumption in response to chronic meat scarcity. More anecdotal ethnographic and ethnohistoric accounts from different parts of the world report that during times of famine, discarded bones fortuitously encountered or associated with known older butchering locations and/or residential middens were gathered and cooked for any remaining grease and marginal bits of dried tissue (e.g., Denig 2000; Lancaster 1966, p. 97; Lee 1966, p. 132; Raum 1940, p. 208).

The implications for zooarchaeological assemblages are clear. Even when high levels of bone fragmentation can be definitively attributed to a cultural origin, interpretations of resource intensification linked to chronic resource scarcity must distinguish among possible alternative scenarios. Some are discussed here, but there are other circumstances where the production of highly fragmented bone to extract grease is unrelated to resource depression. For instance, Dirar (1993) describes traditional Sudanese fresh bone processing techniques which involve crushing and breaking animal bones into small fragments, fermenting the resulting mass and consuming the product. Recognition that multiple circumstances produce seemingly similar taphonomic attributes can catalyze researchers into searching for additional evidence to distinguish among the different scenarios discussed above. For instance, in Gould's (1996) study, high levels of bone fragmentation involved highly durable and very low-yielding parts such as maxillary teeth. Similarly, there may be distinctive taphonomic patterns associated with processing old or partially weathered bones that can distinguish seasonal from chronic shortages.

### Revisiting Zooarchaeological Methodology: How Do We Identify Intensification?

Standard zooarchaeological procedures identify potential cases of resource depression and intensification by changes in the abundances of large-sized prey (which, under many circumstances, are high-ranked; Broughton *et al.* 2011) relative to smaller-sized, lower-ranked animals and through reductions in the diet breadth *via* changes in assemblage evenness and richness. Although these assemblage-level characteristics can provide overall measures of diet breadth, these values can be influenced by a variety of factors, including the kinds of hunting technology used to acquire prey (e.g., Bird *et al.* 2009; Lupo and Schmitt 2005; Ugan and Bright 2001). Taphonomic evidence is often viewed as playing a critical (yet adjunctive and supporting) role for changes in prey abundances. But analysts typically search for evidence of any or all of the taphonomic indicators discussed in this paper. If any one of these taphonomic attributes is identified (especially in the remains of high-ranking prey), then the inference of intensification resulting from resource depression is supported. As discussed here, the use of any of these taphonomic attributes is not well supported by ethnographic record or actualistic studies. Furthermore, the practice of conflating different taphonomic attributes as indicators of the same or similar

process may mask important circumstantial differences between different attributes. Do elevated cut mark frequencies and highly fragmented bone manifest the same process? In some cases, the answer is no, and analysts need to revisit how intensification, especially resulting from resource depression, is identified.

Furthermore, analysts might start to broaden their view of how intensification might be reflected by different taphonomic indicators. For example, the frequency of human-inflicted tooth and gnaw marks could also potentially yield important information about processing effort. After the tissue is softened by thermal techniques, people can use their own masticatory abilities and/or their hands as tools to remove attached edible tissues. Forest foragers spend considerable time chewing, sucking, and handpicking bits of tissue from cooked animal parts before the bones were discarded. These activities can leave taphonomic traces in the form of tooth marks and gnaw marks on the bones (see Landt 2007). While these taphonomic indicators were not explored in this analysis, we predict that these damage patterns are likely to be very common in assemblages subjected to thermal processing and have high potential to be used as indices for intensification.

## Conclusions

Despite the results of these analyses, we believe that taphonomic attributes have the potential for indexing differential processing effort. Currently, however, the way these data are recognized and used in standard zooarchaeological analyses potentially conflates a variety of different processes. Specifically, standard procedures used in zooarchaeological analyses tend to view all of the indicators discussed—increased cut mark frequencies, elevated fragmentation patterns, and nonselective marrow exploitation—as homogenous markers of intensification arising from the same set of cultural and/or ecological circumstances. But this is an assumption that has virtually no independent actualistic support. The results of the analyses conducted here do not derail the use of classic taphonomic indicators as adjunctive evidence for resource intensification, but they do invite a closer examination of how different taphonomic indicators (or suites thereof) vary in response to intensification. Intensification can be manifested in many different ways and can be independent of resource depression or scarcity and dietary stress. Dietary stress, itself, can have multiple manifestations in kind and in tempo and have very different behavioral and physiological outcomes for human populations. Are different kinds of resource depression and scarcity reflected by different suites of taphonomic indicators? This and related questions remain, as yet, unasked, but answering them appears to be critical to the future use and value of taphonomic indicators as indices of resource intensification. If taphonomic indicators can be indexed to specific kinds of intensification and, by extension, resource scarcity (qualitative *versus* quantitative differences), then these data will offer real explanatory potential. Although these specific processes may be difficult to identify, especially when considering the spatiotemporal scale of the archaeological record (Grayson and Delpech 1998; Lyman 2003b), additional taphonomic data on prey processing from ethnoarchaeological contexts will doubtless afford some fruitful insights.

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## Appendix 1

Table 8

**Table 8** Anatomical part weights and FUI for an adult male blue duiker caught in a net hunt in Grima, January 2000

Total carcass weight	9,375		Breast plate (meat/bone)	375			
Head/neck	1,400		Internal organs	2,125			
Tongue	38		Left half (eviscerated)	2,200			
Wet skin	1,225		Right half (eviscerated)	2,200			
Part/segment	Meat	Wet bone	Dry bone	Meat	Wet bone	Dry bone	FUI
Cranium/mandible	134.0 <sup>a</sup>	200.0 <sup>b</sup>	56.0	–	–	–	278.00
Cervical	125.0	47.0	14.0	–	–	–	158.0
	Paired segments/parts—left			Paired segments/parts—right			
Thoracic/rib	102.0	69.0	13.0	98.0	67.0	10.5	312.50
Lumbar	94.0	31.0	5.1	77.0	18.5	5.1	210.30
Innominate/sacrum	74.0	30.0	7.1	63.0	42.0	8.9	193.00
Scapula	46.0	9.7	3.2	59.0	9.5	3.1	58.95
Humerus	48.0	11.5	6.3	45.0	11.5	6.2	51.75
Radius/ulna	21.5	9.4	5.1	22.0	7.0	5.2	24.80
Metacarpal	4.9 <sup>d</sup>	4.3	3.3	3.0	4.5	3.1	–
Front foot	5.2	–	–	5.0	–	–	–
Femur	276.0	19.5	9.7	286.0	19.8	9.2	291.20
Tibia <sup>c</sup>	49.0	18.5	11.6	53.0	19.5	12.3	58.05
Metatarsal	10.7	7.4	5.1	7.5	7.7	5.0	–
Rear foot	5.3	–	–	5.0	–	–	–

All weights are in grams

FUI Food Utility Index

<sup>a</sup> Skin, external meat, and tongue

<sup>b</sup> Includes brain and eyes

<sup>c</sup> Includes calcaneus and astragalus

<sup>d</sup> Largely skin



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